AMERICAN MUSEUM NOVITATES

Number 932 Published by THE AMERICAN MUSEUM OF NATURAL HISTORY New York City June 30, 1937

THE MORPHOLOGY OF WARDITE

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At the time of the study of the phosphate nodules of Fairfield, Utah, in preparation for the recently completed work upon gordonite (Pough, 1937), it was found that several specimens showed what appeared to be good crystals of the mineral wardite ($2\ Na_2O.CaO.6Al_2O_3.4P_2O_5.17H_2O$). The nodules were collected by Arthur Montgomery and Edwin Over in the fall of 1936, reworking the locality from which the original specimens described by Larsen and Shannon (1930) came. As the crystallography of this mineral was not studied in the original descriptions, it was planned to do this, and, at the same time, to bring out the relationship of these crystals to those described by Lacroix (1910) under the name soumansite. The original material of Larsen and Shannon was also examined, but only a few crystallized specimens were found and most of these did not equal those collected by Montgomery and Over.

The crystals occur in vugs in the phosphate nodules, and, like the other minerals, are the result of the alteration of the variscite. Wardite appears to be one of the later minerals and is relatively common, far more so than the gordonite. It occurs in crusts of varying thickness, with well-developed crystals in the open vugs. Most of the crystals are not suitable for goniometric measurement, however, for many are deeply corroded and some are coated with a thin blue coating of a mineral resembling millisite. The crystals seldom exceed .5 mm. in size and are pale blue in color. They form tetragonal bipyramids and are, perhaps, the most easily recognizable of all the crystals of the nodules. The wardite crystals are usually in the center of a vug, surrounded by the yellow pseudowavellite, and often attached to it. Lehiite and millisite are later and coat the crystals or fill in the remainder of the cavity in some specimens.

Goniometric measurement of the crystals gave disappointing results; for despite their apparent perfection, the angles were unsatisfactory on many of the crystals, and the good ones give most surprising results. The dominant bipyramid gave especially inconsistent readings; some of which were to be expected from the striated nature of the face, but not all of which can be explained in that fashion. Many crystals were

measured; of these, fifteen were selected as being the most perfect with the best signals, and the elements calculated from these averages.

As may be seen from the measured angles in table I, the variation in the readings on the dominant second order bipyramid extend over a wide range, resulting in considerable uncertainty about the exact symbolization of that form. The average of 37 readings was used to obtain a ρ angle of 54° 55′, and it cannot be far off. This form may not, however, be taken as the unit, for then the narrower but much more consistent form which is to be called (201) would receive a much more complex symbol; even less likely than the (13·0·12) given the dominant form. If the angles of this form were reasonably consistent, this course might not

TABLE I.—Wardite: Two-circle measurements on fifteen crystals

Forms	No. of Faces	Measured Range ϕ	Measured Range ρ	Measured Mean ϕ	Measured Mean ρ
c 001	15	–° –′ –° –′	–° –′ –° –′	° ′	—° ′
a 100	14	– – – –	– – – –		——
t 13.0.12	37	——	53 29 – 57 38	– –	54 55
. 907	4	——	58 11 – 59 55	– –	59 27
u 201	29	——	68 11 – 69 57	– –	69 08
. 301	1	——		– –	74 56
. 447	2	——	46 40 – 47 31	– –	47 05
. 134	4	16 43 – 18 20	40 22 – 49 30	17 44	45 27
. 4.9.12	21	20 53 – 26 44	44 04 – 51 52	23 47	47 20
. 6.10.15	12	27 51 – 32 41	44 11 – 49 53	29 48	46 29

be justifiable, but inasmuch as they are so variable the other alternative seems preferable. Futhermore, there is adequate corroboration in Lacroix (1910), in the description of the crystals of soumansite. His crystals were poor, but his form $b^{1/2}$ has a ρ angle of 42° 40′, which corresponds very favorably with the ρ angle of 42° 51′ which the form (112) would have if it were present on the crystals from Utah. There can be little question that the unit has been properly selected.

Table II is the angle-table for the mineral. All of the forms except b (112) were observed in the present study; this form is from Lacroix as discussed above. In addition to the certain forms, to which letters have been assigned, there are several others listed below which must be

called uncertain and requiring confirmation. Some of these were observed frequently, as may be seen in table I, but their observed angles were too inconsistent to warrant their acceptance. The symbols are relatively simple and the averages not far off from the calculated angles. (4·9·12) and (6·10·15) were often seen as thin truncations lying between the faces of the dominant bipyramid. Although they look like good forms on the crystals, the measurements are bad, with the signal often falling in a train-of-reflection running from one face to the next. One form (301) was seen but once, and while reasonably good in its measured angle it was not confirmed and cannot be accepted as certain.

TABLE II.—Wardite ($2Na_2O.CaO.6Al_2O_3.4P_2O_5.17H_2O$)
ANGLE-TABLE

Tetragonal-ditetragonal bipyramidal class
p_0 = 1.3117 a:c = 1:1.3117

FORM	SYMBOL	ϕ °	'	ρ °	'
c	001	—	—	—	—
a	100	00	00	90	00
t	13.0.12	00	00	54	52
u	201	00	00	69	08
b	112	45	00	42	51
	FORMS REQUIRING CONFIRMATION				
.	907	00	00	59	20
.	301	00	00	75	45
.	447	45	00	46	40
.	134	18	26	46	03
.	4.9.12	23	58	47	07
.	6.10.15	30	58	45	33

The usual habit of the crystals is shown in Figs. 1 and 2. On most of the crystals, especially the smaller ones, the combination of forms is simple with only the base and the dominant bipyramid present. In some, however, usually the larger ones, the additional forms of Fig. 2 are present; (13·0·12) still dominant, but truncated by a narrower (201) and a still narrower prism. The edges between the faces of (13·0·12) are in most cases truncated by some of the uncertain forms. As these forms are so uneven and variable, it is probable that they developed through corrosion.

c (001) is usually present as a small, very brilliant face and is excel-

lent for orientation purposes. t (13·0·12) is large, but commonly striated parallel to its intersection with the base and u (201), and rarely gives a sharp signal. u is narrower and duller than t, but is usually not regularly striated and gives a sharp signal. a (100) is narrow and rarely gives a good signal, but is easily recognized from the zonal relations when it occurs.

The corrosion of the wardite crystals is interesting. On one specimen the pyramidal forms were corroded so deeply that the crystals resembled simply terminated tetragonal prisms. The crystals were exceedingly minute and the surfaces developed appeared to be rounded, without any evidence of actual prism planes. Through this attack, the base survived as a brilliant, unetched form, showing no signs of the

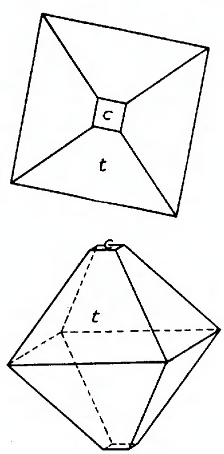

Fig. 1

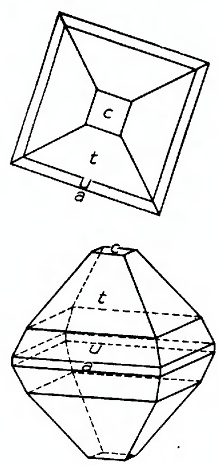

Fig. 2

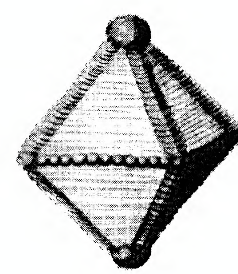

Fig. 3

solution which had almost destroyed the rest of the crystal. A more common etching only rounded the edges, with less complete destruction of the whole. The base seems always to survive and has remained brilliant on all the crystals studied.

An interesting example of selective incrustation was observed on some of the crystals with the coatings of millisite. Small spheres of the later mineral were often observed attached to the bases of the wardite crystals. A further stage in this growth has resulted, in some specimens, in the formation of millisite shelves along the edges of the bipyramids, overlapping each other up the crystal like fungi growing up a dead log. Fig. 3 represents such a selectively coated wardite crystal. Finally, the whole crystal may be coated over, usually with a thickening of the

incrustation at the edges between the pyramid faces. Beneath the millisite, the original faces are corroded and dull.

The study has shown the morphological similarity of wardite and soumansite. The new c is about double that of Lacroix; 1.3117 as compared to 0.7672, but gives more satisfactory indices. The crystals are remarkable in being dominated by a form with a symbol as complex as (13·0·12), but the measurements permit no other choice. A new locality may yield crystals which will permit confirmation of some of the uncertain forms, but it is not likely that they can be checked by additional measurements of Fairfield, Utah crystals, unless far better ones are found than are now available.

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